MILLER INSTITUTE NEWSLETTER

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Miller Fellow Focus: Josh Ruderman

2011 was a momentous year for particle physics. The Large Hadron Collider (LHC), a 17 mile circular proton-proton collider located on the Swiss-French border near Geneva, has successfully collected a very large dataset of proton collisions at an energy of 7 teraelectron-volts (TeV). These are the highest energy particle collisions created by humans, and they enable us to produce new particles and probe length scales all the way down to 10^(-20) meters, 10 orders of magnitude smaller than the size of a hydrogen atom! The 2011 dataset has allowed experimentalists to hone in on the elusive Higgs boson.

This great leap in experimental progress is being followed very closely by Joshua Ruderman, a theoretical particle physicist and first-year Miller Fellow. Josh specializes on the relationship between new, speculative, theories of particle interactions and the emerging data, from experiments such as the LHC, that can be used to discover and exclude these theories. Josh completed his PhD studying under Nima Arkani-Hamed at Princeton University, where he developed new particle models of dark matter and studied the novel LHC signals that are predicted by these models.

The so-called Standard Model of particle physics has been amazingly successful at explaining all phenomena observed so far in a succession of higher and higher energy particle colliders. The missing ingredient of the Standard Model has been an explanation for the origin of the masses of all of the fundamental particles, such as the electron, muon, and quarks. We observe these particles to have masses, but the precise dynamics responsible for generating these masses have remained a mystery.

The simplest explanation of the Standard Model particle masses posits that the Universe is filled by a Higgs field. Particle masses are determined by how strongly they interact with this field (for example, the electron, which is very light, compared to other particles, interacts with this field very weakly). Excitations of this field take the form of a new

CALL FOR NOMINATIONS

Miller Fellowship nominations
due Thursday, September 6, 2012

Miller Research Professorship applications
due Thursday, September 13, 2012

Visiting Miller Professorship Departmental nominations
due Friday, September 14, 2012

Please see pages 3 & 7 for details. For complete information on all our programs, visit: http://millerinstitute.berkeley.edu

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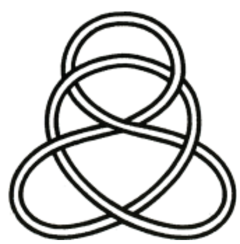
particle of unknown mass, known as the Higgs boson. This theory is mathematically beautiful, but it has lacked experimental verification because the Higgs boson is notoriously difficult to detect in particle collisions. For the past decade, physicists have only known that the Higgs, if it exists in its simplest form, must be heavier than 114 gigaelectronvolts (GeV, where 1000 GeV = 1 TeV), because otherwise it would have shown up in the datasets of previous particle colliders. The key questions are: does the Higgs exist, and if so, what is its mass?

In enters the LHC. Using the 2011 dataset, experimentalists have excluded, with a probability of 95%, nearly all possible Higgs masses except for the narrow range 122.5 - 127 GeV. Intriguingly, the two LHC detectors, ATLAS and CMS, both see collision events in their datasets consistent with the existence of a Higgs boson with a mass of about 125 GeV, smack in the middle of the allowed region! Once produced at the LHC, the Higgs boson is not expected to live very long, instead it will decay after only 10^(-22) seconds into other Standard Model particles, such as photons or muons. The Higgs is searched for by looking for these decay products in configurations that are likely to have resulted from the decay of a Higgs boson. Figure 1 shows a proton-proton collision, collected on October 22, 2011, that is consistent with the production of a Higgs boson of mass 125 GeV that then decayed into two photons. Figure 2 shows data from a collision collected on September 14, 2011, that is consistent with a Higgs boson decaying to 2 muons and 2 anti-muons.



It is too early to say definitively whether or not the Higgs boson has been discovered with a mass of 125 GeV. Right now, there is still a few percent chance that all of the candidate Higgs events are actually rare events coming from the other Standard Model particles, with no Higgs boson produced. Fortunately the issue will soon be resolved: in 2012, the LHC is expected to collect 3 times more proton collisions than 2011, and this will be enough data to confirm, or rule out, the existence of a Higgs boson in its simplest form.

The mass of the Higgs boson is of great interest to Josh because the properties of the Higgs open up a window to new physics beyond the Standard Model. Because the current data hint strongly that the Higgs mass is 125 GeV, many theorists, including Josh, are now tentatively taking a “guilty until proven innocent” attitude and they are already beginning to explore the theoretical implications of the possible existence of a Higgs boson with a mass of 125 GeV. Although the Higgs field explains the mass of the Standard Model particles, like the electron, it leads to a new question: why does the Higgs boson itself have the mass that it has? (It is often the case in particle physics that learning the answer to one question leads one to ask even more fundamental questions). Particle theory actually suggests that the Higgs boson should be much heavier than it is: this is known as the “hierarchy problem.” A leading solution to the hierarchy problem is supersymmetry, a hypothetical symmetry between bosons and fermions that can explain the mass of the Higgs boson.

Josh, working with UC Berkeley Professor Lawrence Hall (a former Miller Fellow & Miller Professor), and graduate student David Pinner, has written the first paper studying the implications of a 125 GeV Higgs boson for supersymmetry. In supersymmetric models, the Higgs boson mass can be calculated. Josh has shown that the simplest form of supersymmetry is now disfavored if the Higgs boson mass is 125 GeV because, roughly speaking, 99% of supersymmetry models predict a Higgs boson that is lighter than 125 GeV. On the other hand, Josh and his collaborators showed that a Higgs boson mass of 125 GeV is naturally generated if certain new dynamics are included with supersymmetry. Therefore, the Higgs mass provides an important diagnostic tool that points the way towards the most promising realizations of supersymmetry.

There is much more that we can learn from the LHC about the Higgs, besides its mass. In particular, the simplest version of the theory precisely predicts the probability that the Higgs boson will decay to different combinations of particles, such as two photons, as in figure 1, or 4 muons, as in

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The Adolph C. and Mary Sprague
Miller Institute for Basic Research in Science
University of California, Berkeley

Call For Miller Research Fellowship Nominations
2013-2016 Term

Nomination Deadline: 6 September 2012

The Miller Institute for Basic Research in Science invites department chairs, faculty advisors, professors and research scientists at institutions around the world to submit nominations for Miller Research Fellowships in the basic sciences. The Miller Institute seeks to discover and encourage individuals of outstanding talent, and to provide them with the opportunity to pursue their research on the Berkeley campus. Fellows are selected on the basis of their academic achievement and the promise of their scientific research. The Miller Institute is the administrative home department for each Miller Fellow who is hosted by an academic department on the Berkeley campus. All research is performed in the facilities provided by the UC Berkeley academic department. A list of current and former Miller Research Fellows can be found at: http://millerinstitute.berkeley.edu/all.php?nav=46

Miller Research Fellowships are intended for exceptional young scientists of great promise who have recently been awarded, or who are about to be awarded, the doctoral degree. Normally, Miller Fellows are expected to begin their Fellowship shortly after being awarded their Ph.D. A short period as a post-doctoral fellow elsewhere does not exclude eligibility. However, applicants who have already completed substantial postdoctoral training are unlikely to be successful except in unusual circumstances. A nominee cannot hold a paid or unpaid position on the Berkeley campus at the time of nomination or throughout the competition and award cycle. Nominees who are non-US citizens must show eligibility for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship. The Miller Institute does not support H1B visa status. The Fellowship term must commence between July 1 and October 1, 2013. Eligible nominees will be invited by the Institute to apply for the Fellowship. Direct applications and self-nominations are not accepted.

*All nominations must be submitted using the Online Nomination System at http://millerinstitute.berkeley.edu/

Nominators will need the following required information to complete the online nomination process:

- Nominee's complete full and legal name
- Nominee's current Institution
- Nominee's complete and current **active** E-mail address, current mailing address and telephone number
- Nominee's Ph.D. Institution and (expected) Date of Ph.D. (month & year required)
- Letter of recommendation and judgment of nominee's promise by the nominator. The Executive Committee finds it helpful in the recommendation letter to have the candidate compared with others at a similar stage in their development.
- Nominator's current **active** E-mail address, title, and professional mailing address (include zip code/campus mail code)

The Institute will provide a stipend of $61,000 with annual increases and a research fund of $12,000 per annum. There is provision for travel to Berkeley for Miller Fellows and their immediate families and a maximum allowance of $3,000 for moving personal belongings. Benefits, including medical, dental, vision and life insurance are provided with a modest contribution from the Miller Fellow. All University of California postdocs are represented by the UAW. Fellowships are awarded for three years, generally beginning August 1, 2013 and ending July 31, 2016. Approximately eight to ten Fellowships are awarded each year. Candidates will be notified of the results of the competition starting in mid-December, and a general announcement of the awards will be made in the spring.

We are grateful for your thoughtful participation in this process and hope that you regard the time you may devote to this effort justified by the contribution you will be making to the careers of distinguished young scientists.

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Miller Research Fellowship Awards 2012-2015

The Miller Institute is pleased to announce the 2012-2015 Miller Research Fellows. Each year, the Miller Institute seeks to discover individuals of outstanding talent and to bring to Berkeley young scholars of great promise. Candidates are nominated for these awards and are selected on the basis of their academic achievement and the potential of their scientific research. The Fellows will be working with Berkeley faculty hosts for a three-year term beginning in the 2012 academic year. A full list of all past and present Miller Fellows is available on our website.

Thomas Bodin
Ph.D. - The Australian National University
Berkeley Department: Earth & Planetary Science
Faculty Host: Barbara Romanowicz

Similarly to medical imaging, where for example acoustic waves are used to image the human body, Dr. Bodin is interested in imaging the Earth's interior using seismic waves generated by earthquakes, and traveling through different structures of the planet. This is called seismic tomography and has been an active area of research in seismology for the last 30 years. He is particularly interested in tackling the problem probabilistically, where one fully accounts for uncertainties both in the observed seismic waves and on the final image of the Earth.

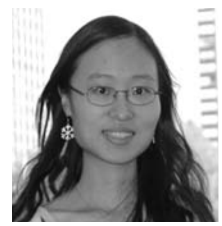
Itay Budin
Ph.D. - Harvard University
Berkeley Departments: CBE/Bioengineering
Faculty Host: Jay Keasling

Lipid membranes are a ubiquitous organizing structure in biology and have evolved as physical environments for a host of fundamental molecular processes. Dr. Budin is broadly interested in understanding the function and evolution of cell membrane components. Specifically, he is exploring two sets of closely connected questions: 1) How does membrane lipid composition affect cellular function? What is the basis for diversity in membrane composition among organisms, tissues, and organelles? 2) How do the membrane's material properties, as determined by lipid composition, regulate cell function? What functions dictate the optimal physical state of cell membranes, which varies considerably in biology? Dr. Budin uses a combination of biophysical approaches and synthetic biology to address these questions.

Qian Chen
Ph.D. - University of Illinois at Urbana-Champaign
Berkeley Department: Chemistry
Faculty Host: Paul Alivisatos

Dr. Chen is tremendously interested in transmuting the inanimate matter into animate. This becomes challenging yet more intriguing when the matter is tiny, down to the nanometer size. The aim is to devise machines of such size, capable of accomplishing physical tasks at a high temporal (i.e. only when a trigger is received) and also a high spatial resolution (i.e. only where the machine resides). These tiny machines whose operations, programmed into them by design, would work in a bottom-up manner: one action in the targeted elementary unit will influence, and even transform the upper-level states.

Xie Chen
Ph.D. - M.I.T.
Berkeley Department: Physics
Faculty Host: Joel E. Moore



Just like the collective vibration of water molecules gives rise to water waves, quantum particles, when in large number and moving together, can exhibit surprising emergent behaviors. One amazing example is the Quantum Hall effect in two dimensional electron systems where currents can flow with quantized conductance accurate to 10^(-8) order. However, our understanding of such quantum many-body phenomena is limited due to our inability to characterize the essential quantum correlation, called 'entanglement', that exists among the particles. Dr. Chen's research interest is in combining ideas from quantum information theory, where entanglement is extensively studied, into condensed matter physics to establish a theory for many-body entanglement. Such a theory would lead to the discovery of new strongly correlated quantum phases in condensed matter systems, a systematic understanding of them and the identification of experimental systems where they can be realized.

Francesco D'Eramo
Ph.D. - M.I.T.
Berkeley Department: Physics
Faculty Host: Yasunori Nomura

The Large Hadron Collider, a particle accelerator located at CERN, is investigating the fundamental laws of nature by colliding protons as well as lead nuclei at the highest energies ever achieved. Proton-proton collisions are providing the first thorough exploration of the Fermi energy scale, where new physics signals are expected. Lead-Lead collisions are studying the quark-gluon plasma properties, a phase of matter which filled the early universe during its first few microseconds. In his research, Dr. D'Eramo works both on predicting signals of new physics at the Fermi scale, and developing new theoretical tools to study the matter produced in heavy-ion collisions.

Gregory Finnigan
Ph.D. - University of Oregon
Berkeley Department: MCB
Faculty Host: Jeremy Thorner

How cells are able to assume an elegant spectrum of shapes and forms is an ongoing question in molecular biology. An attractive candidate that allows for great flexibility at the nanoscale level is the septin family of proteins. Septin subunits combine into small core complexes that can also be assembled into long filaments. A remarkable diversity of higher-order geometries can be generated by septins including bundles, sheets, gauzes, hour-glass shapes, and rings. Dr. Finnigan will investigate the molecular mechanisms responsible for the assembly and regulation of septin complex geometries within budding yeast. He will utilize a combination of genetic, molecular, and biochemical approaches in these studies of cytoskeletal structure and intracellular signaling cascades.

Timofey Frolov
Ph.D. - George Mason University
Berkeley Department: Materials Science & Engineering
Faculty Host: Mark Asta

Dr. Frolov's research focuses on thermodynamics of interfaces and phase equilibrium. His thesis work was devoted to the development of thermodynamic theory of grain and phase boundaries that includes effects of nonhydrostatic stresses, temperature and chemical composition. The developed theory was applied to study interface properties in metallic systems using atomistic simulations. Additional areas of research include: diffusion, premelting, modeling of homogeneous and heterogeneous nucleation, and transitions at interfaces.

Chen Li
Ph.D. - Georgia Institute of Technology
Berkeley Departments: Integrative Biology/ EECS
Faculty Hosts: Robert J. Full/ Ronald S. Fearing

Similar to the emergence of personal computers thirty years ago, robots are on the verge of becoming a major part of everyday life. Most existing robots can already operate effectively from immobile stations (e.g., car welding robots) or on controlled, idealized surfaces (e.g., vacuuming robots); however, locomotor performance is still generally poor in complicated, dynamic terrain (e.g., stairs). By contrast, animals nimbly move about in nature, and provide a source of inspiration for the design of robots with improved locomotor capabilities. Dr. Li is interested in understanding the biomechanics and neurosensory control of legged locomotion, particularly in complex environments. He will study both model animals (insects) and physical models of organisms (legged robots) moving in complicated terrain, to discover how sensing capabilities as well as the morphology and dynamics of body and limbs interact with the environment to control movement and determine performance. These principles will aid the development of robots suited for the real world with locomotor capabilities beginning to approach those of biological organisms.

Milo Lin
Ph.D. - California Institute of Technology
Berkeley Department: Chemistry
Faculty Host: David Chandler

Dr. Lin is interested in how proteins perform their functions. His focus is on allostery, whereby binding of a ligand to its (activator) site on a protein leads to enhanced or suppressed activity of a remote (effector) site on the protein. In this sense, allosteric proteins are logic gates within the cell. Using statistical mechanical and computational methods, his goal is to understand allostery at the level of prediction.

Steven Sam
Ph.D. - M.I.T.
Berkeley Department: Mathematics
Faculty Host: David Eisenbud

Dr. Sam is interested in the interactions between algebraic geometry, commutative algebra, and invariant theory. Algebraic geometry and commutative algebra are the study of the geometry and algebra of systems of polynomial equations and invariant theory is the study of symmetries of such systems. In particular, Dr. Sam studies questions such as how to calculate free resolutions, how to describe moduli spaces, and finding connections with other subjects. Such topics have been considered for a long time now, so he is especially interested in integrating modern techniques such as representation theory, sheaf cohomology, and computer algebra.

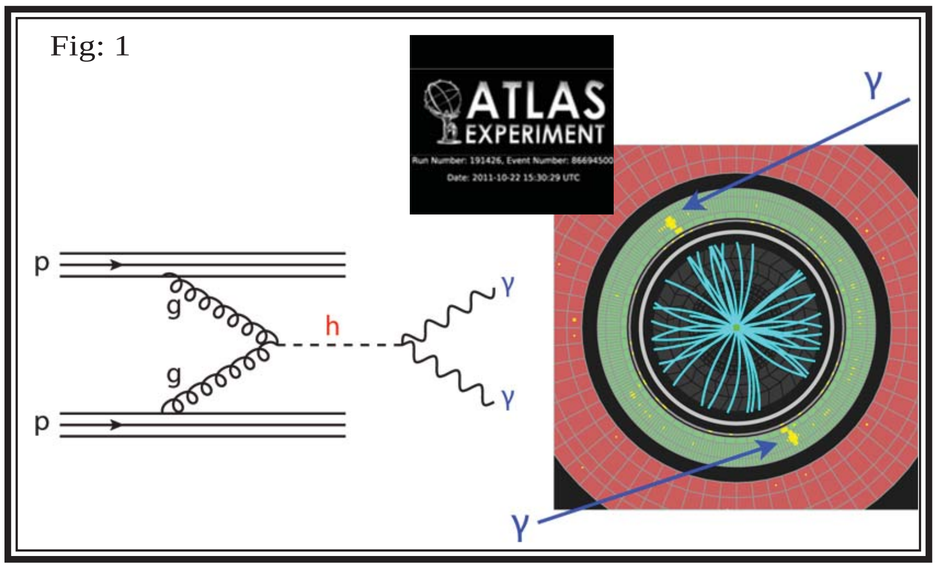
Sa Kan Yoo
Ph.D. - University of Wisconsin-Madison
Berkeley Department: MCB
Faculty Host: Iswar Hariharan

A fundamental unresolved question in biology is how organ size is determined. In a similar vein, how organs regenerate upon tissue damage is also a fascinating problem. Dr. Yoo will address these central questions, using the fruit fly, Drosophila melanogaster and the tropical fish, Danio rerio. He hopes his research will provide novel insights into the regulation of organ size and therapeutic strategies in regenerative medicine.

figure 2. Meanwhile, new physics can modify these decay probabilities, which are known as branching ratios. It will be crucial for the LHC to produce many Higgs bosons and to measure all of the different Higgs branching ratios as precisely as possible. Josh showed, with Lawrence and David, that the very extensions of supersymmetry that can explain why the Higgs boson mass is 125 GeV also tend to increase the probability that the Higgs boson decays to two photons. This prediction will be tested by the 2012 LHC data.

There is much to look forward to regarding the LHC, which will run at 8 TeV for the rest of 2012. Then, after a two year shutdown to upgrade the energy, the LHC will resume in 2015 with an energy of about 14 TeV: a doubling over the 7 TeV energy used in 2011. Future LHC collisions will allow for the precise measurement of Higgs properties. Even more interestingly, the increased energy may allow experimentalists to produce and discover new particles beyond the Standard Model with even higher masses. As the LHC measurements evolve, Josh plans to continue to study their implications for the fundamental interactions of our Universe.

Figure 1: a candidate Higgs event produced at the LHC is shown to the right, where two protons have collided and produced two photons. This event could have come from the process shown in the diagram to the left, where two gluons from the protons combine to form a Higgs boson, which then decays to two photons.



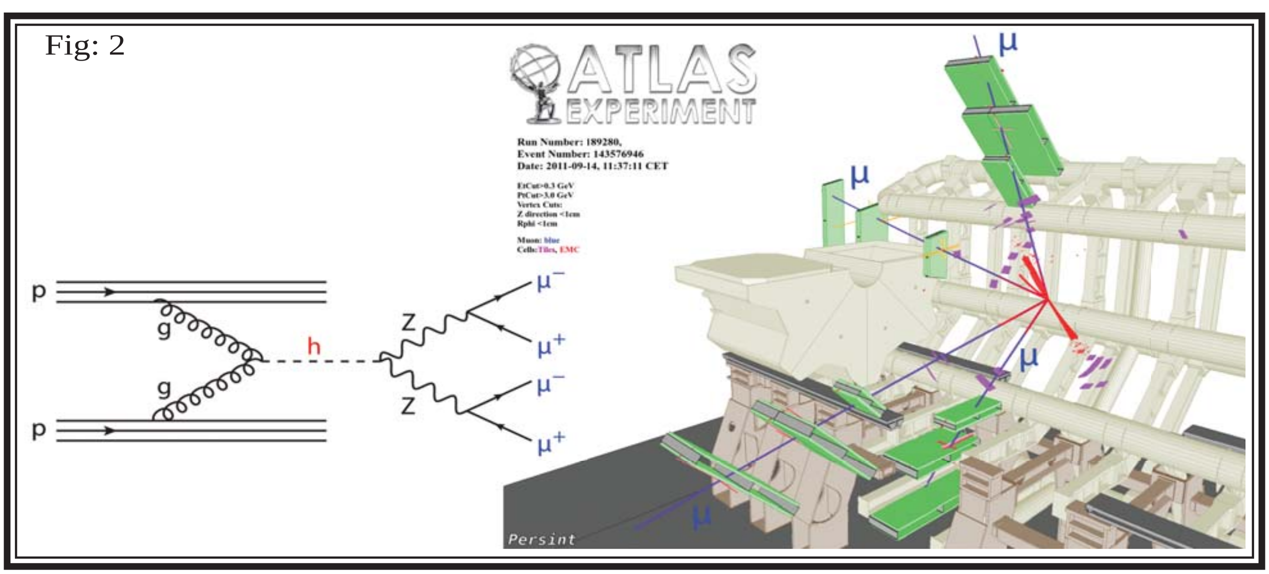


Figure 2: a candidate Higgs event is shown to the right, where a proton-proton collision has produced 2 muons and 2 anti-muons. This event could be due to the diagram shown to the left, where a Higgs decays to two Z bosons, each of which decays to a muon and an anti-muon.

The Adolph C. and Mary Sprague Miller Institute for Basic Research in Science University of California, Berkeley

Call for Applications & Nominations

Miller Research Professorship

Applications from University of California faculty for Miller Research Professorship terms in the 2013-14 academic year will be accepted online beginning in June 2012. The purpose of the Professorship is to release members of the faculty from teaching and administrative duties and allow them to pursue research on the Berkeley campus. Appointees are encouraged to follow promising leads that may develop in the course of their research.

Applications are judged competitively and are due by Thursday, September 13, 2012. It is anticipated that between five to eight awards will be made.

Visiting Miller Professorship

The Advisory Board of the Miller Institute for Basic Research in Science invites Berkeley faculty to submit online departmental nominations for Visiting Miller Research Professorship terms in Fall 2013 or Spring 2014. The purpose of the Visiting Miller Professorship is to bring promising or eminent scientists from any place in the world to the Berkeley campus on a short-term basis for collaborative research interactions.

Online nominations will be accepted beginning in June 2012 and are due by Friday, September 14, 2012.

For more information please visit: http://millerinstitute.berkeley.edu

Awards and Honors

March 5, 2012: **Nicholas P. Jewell** (Miller Professor Fall 1994, Fall 2004), professor of biostatistics and statistics at the UC Berkeley School of Public Health, was awarded the Harvard School of Public Health's 2012 Marvin Zelen Leadership Award in Statistical Science.

March 5, 2012: **Marvin L. Cohen** (Miller Professor 1969-70, 1976-77 &1988) Carnegie Mellon University will award its 2011 Dickson Prize in Science to Marvin L. Cohen, one of the most influential condensed matter physicists in the world.

February 21, 2012: **James Sethian** (Miller Professor Spring 2011) and Robert Saye, mathematicians who both hold joint appointments with the Lawrence Berkeley National Laboratory (Berkeley Lab) and the University of California (UC) Berkeley, have won the 2011 Cozzarelli Prize for the best scientific paper in the category of Engineering and Applied Sciences.

February 3, 2012: **Chancellor Robert J. Birgeneau** (Advisory Board Member) is the recipient of the 2012 Clifford G. Shull Prize of the Neutron Scattering Society of America (NSSA) with the citation: *"For his seminal scientific, tireless leadership, and devoted mentoring in the field of neutron scattering."*

February 2012: **Sébastien Merkel** (Miller Fellow 2004 - 2006) was awarded the 2011 European Mineralogical Society Research Excellence Medal.

Miller Institute News
Spring 2012
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Next Steps

The Miller Institute congratulates the following Miller Fellows on their next endeavors.

Genevieve Graves
Henry Norris Russell Fellow
Department of Astrophysical Sciences
Princeton University

Scott Morrison
Senior Lecturer
Mathematical Sciences Institute,
The Australian National University

Daniel Rabosky
Assistant Professor
Department of Ecology & Evolutionary Biology
University of Michigan

Birth Announcements

Heather Knutson (Miller Fellow 2009 - 2012) & Paul Nerenberg announced the birth of their son, Zachary Phillip Nerenberg, born March 2nd.

Ioana Dumitriu (Miller Fellow 2003 - 2006) & David Stalder announced the birth of their son, Gabriel Mircea Stalder, born November 2nd.

Obituaries

Professor Richard F. W. Bader
(Visiting Miller Professor Fall 1993)

New

The Miller Institute is now

LinkedIn

Online Newsletter

The Miller Institute invites you to enjoy our previous e-newsletters by visiting millerinstitute.berkeley.edu.
Select NEWS.

The Miller Institute is "dedicated to the encouragement of creative thought and the conduct of research and investigation in the field of pure science and investigation in the field of applied science in so far as such research and investigation are deemed by the Advisory Board to offer a promising approach to fundamental problems."